INTRAOPERATIVE ANEURYSMAL RUPTURE: CLINICAL OUTCOME FOLLOWING OPEN SURGERY OR ENDOVASCULAR TREATMENT

Novak Lakićević[1], Branko Prstojević[2], Lukas Rasulić[2], Ljiljana Vujotić[2], Ivan Vukašinović[2], Biljana Miličić[2], Andrija Savić[2], Bojana Živković[2], Krešimir Rotim[3] and Miroslav Samardžić[2]

[1]Clinical Department of Neurosurgery, Clinical Center of Montenegro, Podgorica, Montenegro; [2]Clinical Department of Neurosurgery, Clinical Center of Serbia, Belgrade, Serbia; [3]Clinical Department of Neurosurgery, Sestre milosrdnice University Hospital Center, Zagreb, Croatia

SUMMARY – The aim of this study was to evaluate and compare the outcomes of intraoperative aneurysmal rupture in patients with subarachnoid hemorrhage undergoing open surgical or endovascular treatment. This retrospective study included 742 patients with aneurysmal subarachnoid hemorrhage treated at the Clinical Department of Neurosurgery, Clinical Center of Serbia, during a three-year period. Among them, 167 (31.15%) were treated by clipping and 33 (16.01%) by coiling in the early phase (≤72 hours). The overall outcome and pretreatment variables were analyzed for each group, including between-group difference according to the occurrence of intraoperative aneurysmal rupture. Intraoperative aneurysmal rupture occurred in 14.7% of microsurgical and 2.4% of endovascular procedures. It was more frequent in early procedures as compared with delayed procedures (27.5% and 9.7% *vs.* 2.2% and 1.1%, respectively). On the contrary, mortality rates were lower in the surgical group (11.4%) than in the endovascular one (60.0%).On the basis of the results obtained, it is concluded that intraoperative aneurysmal rupture is more frequent after open than after endovascular treatment, but clinical outcome is more favorable in the former group.

Key words: *Intracranial aneurysm – surgery; Intraoperative complications; Aneurysm, rupture; Subarachnoid hemorrhage; Aneurysmal clipping*

Introduction

Intraoperative aneurysmal rupture (IAR) is the most dramatic and potentially devastating complication of open or endovascular aneurysm occlusion[1,2]. The estimated rate of IAR during endovascular treatment ranges between 2% and 5%, with associated high morbidity and mortality[3]. Advances in endovascular techniques, especially the introduction of stents, may lower the incidence of IAR and its consequences. On the other hand, the incidence of IAR during open surgery ranges from 5% to 50%[2,4-6]. The large variations in the reported incidence depend on whether minor leaks were considered or not. Several studies exclude minor leaks or small bleeds that occur during clip application[1,7-10]. Both early open and endovascular treatment are associated with a higher incidence of IAR[3,6,8-12]. The majority of these minor events were well managed and did not influence the outcome[10], but significant IAR has clearly been associated with poor outcome, particularly basilar aneurysms[13,14], and the associated mortality may be up to 70%, especially in case of the parent vessel occlusion[7]. Although IAR during open and endovascular surgery cannot be directly compared in all respects, the fact that IAR occurs less often during endovascular procedures[15] calls for further examination. The aim of this study was to

Correspondence to: *Bojana Živković, MD, MS*, Clinical Department of Neurosurgery, Clinical Center of Serbia, Koste Todorovića 4, Belgrade, Serbia
E-mail: zivkovicbojanamd@gmail.com

Received September 3, 2014, accepted October 2, 2014

analyze some aspects of IAR during both modalities of aneurysm treatment.

Patients and Methods

Patient population

This retrospective study included all patients with aneurysmal subarachnoid hemorrhage (SAH) treated during a three-year period (from January 2009 to December 2012) at the Clinical Department of Neurosurgery, Clinical Center of Serbia. Data were collected from 742 patient histories. There were 536 (72.23%) patients treated by aneurysmal clipping and 206 (27.77%) patients treated by endovascular treatment. Patients treated surgically formed group A and patients that were treated endovascularly formed group B (Table 1). Detailed analysis included patient age, gender, clinical status (using Fisher and World Federation of Neurosurgical Societies (WFNS) grade), type and timing of treatment conducted, incidence and timing of IAR, treatment outcome and mortality rate.

The results of treatment were analyzed using modified Rankin Scale (mRS) that divides treatment outcome into 6 groups: (0) no symptoms; (1) no significant disability; able to carry out all usual activities, despite some symptoms; (2) slight disability; able to look after own affairs without assistance, but unable to carry out all previous activities; (3) moderate disability; requires some help, but able to walk unassisted; (4) moderate disability; unable to attend to own bodily needs without assistance, and unable to walk unassisted; (5) severe disability; requires constant nursing care and attention, bedridden, incontinent; and (6) death.

On the analysis, we also used our own modification of Rankin Scale with outcome results clustered in three groups, used when the sample for statistical analysis was too small. Our modification divides treatment outcome into three categories: (1) good condition, including slight disability; (2) moderate to severe disability; and (3) death.

Table 1. Total number of endovascular and microsurgical procedures for intracranial ruptured aneurysms (with previous subarachnoid hemorrhage) in patients with or without intraoperative aneurysmal rupture (IAR) during intervention

	Microsurgery	Endovascular coiling
IAR	79 (14.7%)	5 (2.4%)
No IAR	457 (85.3%)	201 (97.6%)
Total	536 (100%)	206 (100%)

Statistical analysis

Statistical analysis was performed using commercially available software (SPSSv8.0; SPSS, Inc. Chicago, IL). The following tests were performed: analysis of descriptive values (number and percentage of cases, mean, minimal and maximal values); and Pearson's χ^2-test. Dependent variables were IAR and Rankin Scale.

The association of independent variables, including age and gender, timing of intervention, stage of the procedure, location and size of the ruptured aneurysm, WFNS and Fisher grades, was considered significant at the level of $p \leq 0.05$.

Results

Group A

The age of these patients ranged from 11 to 75 years, average 51 years. The gender distribution (male *vs.* female) was 183 (34%) *vs.* 353 (65.8%) for the whole group and 45 (57%) *vs.* 34 (43%) for those with IAR. IAR occurred in 79 (14.7%) patients. IAR occurred in 46 (27.5%) out of 167 early operated patients (≤72 hours) and in 33 (2.2%) out of 369 patients with delayed surgery (Table 2). The majority of IARs (58.2%) occurred during aneurysm dissection, 32.9% during clip application and 8.9% during brain retraction. The differences were statistically significant (χ^2-test, p=0.40). There was a clear trend toward better outcome after IAR during aneurysmal clipping, although the difference was not statistically significant (Table 3).

Table 2. Incidence of intraoperative aneurysmal rupture (IAR) during early open and endovascular surgery

	Microsurgery	Endovascular coiling
IAR	46 (27.5%)	3 (9.1%)
No IAR	121 (72.5%)	30 (90.9%)
Total	167 (100%)	33 (100%)

Table 3. Clinical outcome according to the stage of surgery at which intraoperative aneurysmal rupture occurred

Phase of operation								
	Brain retraction		Dissection		Clipping		Total	
Rankin Scale*	n	%	n	%	n	%	N	%
Good condition, including slight disability	1	28.57	18	39.13	12	46.15	32	40.50
Moderate to severe disability	4	57.14	22	47.92	12	46.15	38	48.10
Death	2	14.28	6	13.04	2	7.69	9	11.4
Total	7	100	46	100	26	100	79	100

*our modification of the Rankin Scale

Table 4A. Distribution of patients undergoing microsurgical treatment according to intraoperative aneurysmal rupture and modified Rankin Scale (mRS)

	Intraoperative aneurysmal rupture					
	Yes		No		Total	
mRS	n	%	n	%	N	%
No symptoms	0	0.0	15	3.3	15	2.8
No significant disability	9	11.4	155	33.9	164	30.6
Slight disability	30	38.0	41	8.9	71	13.2
Moderate disability	14	17.7	61	13.3	75	14.0
Moderate/severe disability	11	13.9	129	28.2	140	26.1
Severe disability	6	7.6	5	1.2	11	2.1
Death	9	11.4	51	11.1	60	11.1
Total	79	100	457	100.0	536	100.0

Table 4B. Patients treated with microsurgical treatment according to intraoperative aneurysmal rupture and postoperative Rankin Scale

	Intraoperative aneurysmal rupture					
	Yes		No		Total	
Rankin Scale*	n	%	n	%	N	%
Good condition, including slight disability	9	11.4	170	37.2	179	33.4
Moderate to severe disability	61	77.2	236	51.6	297	55.4
Death	9	11.4	51	11.1	60	11.1
Total	79	100	457	100.0	536	100.0

*our modification of Rankin Scale

The χ^2-test demonstrated a statistically significant difference between the groups with and without IAR according to the outcome measured with mRS (χ^2-test, p=0.000). Except for mortality rate (which was almost identical, 11.4% and 11.1%), significant outcome differences were recorded both in the group with and without IAR. In the IAR group, none of the patients was free from symptoms, while in the non-IAR group there were 3.3% of such patients. Outcome with no disability after treatment was significantly more frequent in the non-IAR group as compared with IAR group (33.9% *vs.* 11.4%). There were more patients with slight disability in the IAR group as compared with non-IAR group (38% *vs.* 8.9%). There was approximately the same number of patients with moderate disability in both groups (17.7% and 13.3%, respectively). We found that even more patients without IAR were in the moderate-severe disability group (probably as a consequence of their status before treatment; 13.9% *vs.* 28%). We found significant difference in the occurrence of severe disabilities: 7.6% in the IAR group and 1.2% in the non-IAR group (Table 4A). Data pooling in order to increase the number of patients *per* group yielded a significant difference in the rate of patients with excellent treatment outcome (no symptoms or disability) between the IAR and non-IAR groups (11.4% *vs.* 37.2%; (χ^2-test, p=0.000). The IAR and non-IAR groups included 77.2% and 51.6% of patients with various degrees of disability, respectively (Table 4B).

The χ^2-test showed no significant outcome differences in patients with IAR according to timing of surgery (χ^2-test, p=0.436). The percentage of patients in good condition was higher in the delayed surgery group as compared to the early surgery group (45.45% *vs.* 28.26%). The percentage of patients with disability was higher in the early surgery group as compared to the delayed surgery group (56.52% *vs.* 42.42%). Mortality was slightly higher in the early surgery group than in the delayed surgery group (15.51% *vs.* 12.12%), but the significance could not be proven, probably due to the small number of patients (Table 5).

We conclude that IAR during aneurysm microsurgery did not affect mortality, but increased the risk

Table 5. Outcome and mortality in patients with intraoperative aneurysmal rupture during early microsurgical procedures compared with delayed treatment after subarachnoid hemorrhage

	Early		Delayed		Total
Rankin Scale*	n	%	n	%	N
Good condition, including slight disability	13	28.26	15	45.45	28
Moderate to severe disability	26	56.52	14	42.42	40
Death	7	15.51	4	12.12	11
Total	46	100	33	100	79

* our modification of Rankin Scale

Table 6. Distribution of patients with previous subarachnoid hemorrhage treated endovascularly according to intraoperative aneurysmal rupture and modified Rankin Scale (mRS)

	Intraoperative aneurysmal rupture				
	Yes		No		Total
mRS	n	%	n	%	N
No symptoms	0	0	71	35.3	71
No significant disability	0	0	102	50.7	102
Slight disability	0	0	16	8	16
Moderate disability	1	20	4	2	5
Moderate/severe disability	0	0	1	0.5	1
Severe disability	1	10	4	2	5
Death	3	60	3	1.5	6
Total	5	100	201	100	206

Table 7. Outcome and mortality in patients with intraoperative aneurysmal rupture during endovascular procedures in early compared to delayed treatment after subarachnoid hemorrhage

	Early		Delayed		Total
Rankin Scale*	n	%	n	%	N
Good condition, including slight disability	1	33.33	19	63.33	20
Moderate to severe disability	1	33.33	9	30	10
Death	1	33.33	2	6.66	3
Total	3	100	30	100	33

* our modification of Rankin Scale

of neurological deficits, especially if occurring during early surgery.

Group B

The age of these patients ranged from 15 to 68, average 47 years. Gender distribution (male *vs.* female) was 66 (31.85%) *versus* 140 (68.15%) for the whole group and those with IAR, which occurred in five (2.4%) of 206 patients, all of them females. IAR occurred in three (9.1%) of 33 early treated patients and two (1.1%) of 173 patients with delayed surgery (Table 2).

Analysis of patients with and without previous SAH treated with endovascular procedures showed the same results in both groups, regardless of whether endovascular treatment was performed after SAH or after non-ruptured aneurysm, and IAR significantly increased their mortality. The number of patients with IAR during endovascular procedures performed after SAH was too small for valid statistical analysis, but the figures suggested poorer outcome and higher mortality in the IAR group (Table 6).

Patients with intraoperative rupture during endovascular treatment showed no outcome differences between the groups divided by timing of the procedure (early in the first 72 hours or later), when analyzed by χ^2-test (p=0.490). Absolute numbers suggested better results in the group with delayed treatment, where there were more patients in good condition as compared with those undergoing early treatment (63.33% and 33.33%, respectively). In both the delayed and early treatment groups, there were approximately 30% of patients with disability. Mortality was higher in the early treatment group as compared with the delayed surgery group (33.33% and 6.66%, respectively), but again with a small number of patients in these groups (Table 7).

Comparative statistical analysis of groups A and B

There was no statistically significant difference between treatment groups according to age or gender, in

Table 8. Clinical outcome according to preoperative World Federation of Neurosurgical Societies (WFNS) grade in patients treated microsurgically

	Outcome measured with Rankin Scale*							
	Good condition, including slight disability		Moderate to severe disability		Death		Total	
WFNS	n	%	n	%	n	%	N	%
1	17	60.7	8	28.6	3	10.7	28	100
2	7	33.3	9	42.9	5	23.8	21	100
3	3	17.6	10	58.8	4	23.5	17	100
4	1	14.3	4	57.1	2	28.6	7	100
5	0	0.0	1	16.7	5	83.3	6	100
Total	28	35.4	32	40.5	19	24.1	79	100

* our modification of Rankin Scale

Table 9. Outcome in patients with intraoperative aneurysmal rupture during microsurgery and endovascular procedures

	Microsurgery		Endovascular		Total
Rankin Scale*	n	%	n	%	N
Good condition, including slight disability	39	49.36	2	20	41
Moderate to severe disability	31	39.24	2	20	33
Death	9	11.39	6	60	15
Total	79	100	10	100	89

*our modification of the Rankin Scale

Fisher grades, or in the location and size of ruptured aneurysm. Regarding the preoperative WFNS grading system, we found no significant difference in the incidence of IAR in patients treated with microsurgical aneurysm clipping either, but patients in better clinical condition had a significantly more favorable outcome (χ^2-test, p=0.002) (Table 8). The number of patients treated endovascularly was too small for valid statistical analysis. There were only 5 cases and all of them were in good WFNS grade.

Between group differences according to treatment modalities were significant; IAR was more likely to occur during microsurgical procedure (14.7%) than during early endovascular procedures (2.4%), with statistical significance (χ^2-test, p=0.000) (Table 1). Furthermore, IAR was more frequent in early procedures, i.e. during microsurgery (27.5%) compared to the mean incidence of 14.7%, and during endovascular procedure (9.1%) compared to the mean of 2.4% (χ^2-test, p=0.0042) (Table 2).

Intraoperative aneurysmal rupture was significantly more frequent in early endovascular procedures (χ^2-test, p=0.034).

Difference in the mortality between patients treated with microsurgery and those undergoing endovascular procedure was statistically significant (χ^2-test, p=0.015). In the microsurgically treated group with IAR, 49.36% of patients were in good condition as compared with 20% in the endovascularly treated group with IAR. There were 39.24% of patients with moderate disability in the microsurgically treated IAR group as compared with 20% in the endovascularly treated group with IAR. In the microsurgically treated IAR group, mortality was 11.39% *versus* 60.0% in the group treated with endovascular procedures and sustaining IAR (Table 9).

In other words, although IAR occurred more frequently (14.7%) during microsurgical intervention, bleeding was easier to control, so IAR did not result in poor outcome and high mortality as compared with non-IAR patients (11% in both groups).

We analyzed all patients with IAR treated in the first hours after SAH by microsurgical or endovascular procedure and found no significant difference in outcome. However, a larger study may reveal statistical difference because mortality tended to be lower

Table 10. Outcome and mortality in patients with intraoperative aneurysmal rupture during microsurgery and endovascular procedure in early period after subarachnoid hemorrhage

	Microsurgery		Endovascular		Total
Rankin Scale*	n	%	n	%	N
Good condition, including slight disability	13	28.26	1	33.33	14
Moderate to severe disability	26	56.52	1	33.33	27
Death	7	15.21	1	33.33	8
Total	46	100	3	100	49

*our modification of Rankin Scale

in the microsurgically treated group (15.21%) as compared to endovascularly treated group (33.33%) (Table 10).

Although IAR was significantly less frequent during endovascular procedures (2.4% in the group with previous SAH), the occurrence of IAR dramatically increased the mortality and postoperative neurological disability.

Discussion

Endovascular treatment using Guglielmi detachable coils was introduced in 1991 and thereafter has become widely accepted as an alternative to surgical clipping, although relative benefits of these two approaches have yet to be established. These two techniques have advantages and disadvantages and this question remains controversial[16,17].

The angiographic occlusion rates of coiling are worse than those after surgical clipping and the annual risk of rebleeding is higher in the first group but it still remains low[18,19]. Moreover, there are concerns about the completeness and durability of endovascular treatment and the possibility of subsequent bleeding. This especially becomes important because many patients are young[19-21]. The introduction of additional stents, in the first place for the treatment of complex aneurysms, has resulted in a higher rate of morbidity and mortality due to thromboembolic complications, especially in the early phase[22]. However, vasospasm and infarction are reported to develop more frequently in patients treated by surgical clipping, despite clot removal, suggesting that surgical manipulation of the arteries is the main cause of local vasospasm[17].

Intraoperative aneurysmal rupture is another complication of both procedures, which is controversial regarding the incidence and outcome, especially concerning the timing of surgery. Certainly, advantages of open surgery are that usually there is immediate access to proximal and distal vessels and removal of the blood from the operative site[11]. Brisman *et al.*[15] also report that IAR during endovascular treatment is more lethal than during open surgery due to the lack of direct exposure and consequent difficulty to control the bleeding.

Irrespective of the above mentioned statements, aneurysms that are difficult to access, such as those in the posterior circulation, complex aneurysms and those in aged patients and/or with high-risk medical conditions, may benefit from endovascular treatment, as there is no need for them to be subjected to more invasive open surgery.

The incidence of IAR is higher in poor grade patients, but it is not necessarily associated with poor outcome[10], independently of patent neurological condition, although there is a clear trend toward increased morbidity and mortality in poor grade patients.

Surgical clipping

Chandler *et al.*[23] define IAR as the bleeding that interrupts and changes the order of microsurgical procedure. The main factors that contribute to IAR are as follows: (1) in the early phase, brain retraction with adherent aneurysms such as superiorly projecting aneurysm of the ophthalmic artery to the frontal lobe, inferiorly projecting aneurysm of the anterior communicating artery to the optic nerve or chiasm, and of the posterior communicating artery to the temporal lobe; (2) inadequate dissection of the aneurysmal neck; and (3) poor application or transposition of the clip[1,24]. Generally, the incidence of IAR is significantly higher in case of aneurysms of the anterior circulation. The majority of IARs occur either during aneurysm dissection or clip application[13]. Our results support this statement with 91% of IARs in these stages of surgery.

Early surgery has been reported to be associated with a higher incidence of IAR. This is due to a higher fragility of the blood clot occluding the rupture site[10]. Although there is clear vulnerability of aneurysm in the early period, some authors do not confirm this statement[2,6]. Similarly to the endovascular treatment, IAR incidence in open surgery increases in higher neurological grade and after rebleeding.

Batjer and Samson[13] report a 19% rate of IAR during surgical clipping, associated with 19% mortality and 22% morbidity. Fridrickson *et al.*[25] report similar results. In our series, IAR occurred in 14.7% of microsurgical procedures and even 27.5% during early surgery. The overall mortality rate was 11.4%, and significant disability was recorded in 39.2% of cases. In cases of IAR during early surgery, the mortality rate was 15.2%, associated with 42.4% significant disability. On the contrary, Leipzig *et al.*[2,6] report on significantly lower rates that were attributed to the increased use of temporary clipping. Furthermore, Sandacioglu *et al.*[6] consider that IAR has no significant impact on surgical outcome, although they identified a trend of morbidity and mortality increase in patients that initially had poor neurological grade.

Logically, IAR is better avoided than treated. This includes adequate exposure, proximal control, use of temporary clip, and sharp dissection[1,2,13,24].

Endovascular treatment

In a meta-analysis of 17 published reports, Cloft and Kallmes[26] found the combined IAR rate of 2.7% with a higher incidence in previously ruptured aneurysms (4.1%) *versus* those that had never bled. Other studies report on similar rates of IAR, 2.6% with mortality rate of 37.3%[12], 2.7%[4,27], and 2% to 3%, respectively[11,28]; in our series, it was 2.4%. On the contrary, Tummala *et al.*[3] found a lower incidence of IAR in ten (1.9%) of 525 recently ruptured aneurysms, but the associated mortality was still high, 40%. The limited number of our cases suggested poor outcome and higher mortality following IAR, especially in case of early treatment. Similarly, Brisman *et al.*[15] report on a very low incidence of IAR (1%) but with no mortality and very low incidence of morbidity (17%).

Generally, it is accepted that previously ruptured and early treated aneurysms are more prone to IAR[3,11,12,28], although some authors believe that the incidence of IAR is not in significant relation with the timing of intervention[9]. Regarding aneurysm location and size, the same authors report that smaller aneurysms, those with an irregular dome, and aneurysms located in the anterior communicating artery or posterior circulation are at a higher risk of IAR.

Iatrogenic ruptures or perforations occur most often with smaller lesions, less than 2 mm in diameter, or according to Ricolli *et al.*[29,30] less than 4 mm. Accordingly, some authors suggest that this complication could be minimized if acutely ruptured aneurysms smaller than 3 mm are not submitted to endovascular treatment. Greater fragility of smaller aneurysms has two possible explanations: the surface area of the initial rupture is proportionally larger in small aneurysms; and small coils that measure 2-3 mm in diameter have a higher shape memory and may therefore have a tendency to cause damage to the weakened site of the initial rupture[28,29]. An additional risk factor is the presence of a 'daughter' aneurysm[3,29]. Larger aneurysms tended to rupture when numerous coils were placed[26]. Several mechanisms of aneurysmal bleeding have been proposed including microcatheter perforation, guide wire perforation, high pressure contrast injection, and blood pressure elevation, although this has become less significant with the use of general anesthesia[17,31]. Generally, the morbidity and mortality rates are lower in perforations caused by microguide wires[26] and prognosis is worse for iatrogenic rupture of the posterior circulation aneurysms compared with those in the anterior circulation[3,26].

Outcome was generally worse in patients presenting in poor neurological grade[20,28]. In those having external ventricular drainage at the time of IAR or if it was done as emergency after IAR, the outcome was significantly better[11,26,28]. A shorter time to control IAR with good control of intracranial pressure and blood pressure are predictive factors of better outcome[3,11].

Conclusions

The reported and our results led us to make the following conclusions:

1. IAR occurs less often during endovascular than microsurgical treatment.
2. Early treatment is associated with a higher incidence of IAR.
3. In patients experiencing multiple bleedings, the incidence and severity of IAR seem to be higher.
4. IAR during microsurgical procedures does not affect mortality, but increases the risk of neurological deficit.
5. IAR during endovascular procedures has poorer outcome and higher mortality.
6. IAR is not necessarily associated with poor outcome, although there is a trend toward increased morbidity and mortality in initially poor grade patients.

References

1. Barrow D. Intraoperative misadventures: complication avoidance and management on aneurysm surgery. Clin Neurosurg. 2001;58:93-105.
2. Leipzig T, Morgan J, Horner T, Payner T, Redelman K, Johnson C. Analysis of intraoperative rupture in the surgi-

cal treatment of 1694 saccular aneurysms. Neurosurgery. 2005;56:455-68.

3. Tummala RP, Chu RM, Madison MT, Myers M, Tubman D, Nussbaum ES. Outcomes after aneurysm rupture during endovascular coil embolization. Neurosurgery. 2001;49:1059-66.
4. Awad IA, editor. Current management of cerebral aneurysms. 1stedn. Thieme, New York, 1993.
5. Kheĭreddin AS, Filatov IuM, Belousova OB, Pilipenko IuV, Zolotukhin SP, Sazonov IA, *et al.* Intraoperative rupture of cerebral aneurysm – incidence and risk factors. Zh Vopr Neirokhir Im N N Burdenko. 2007 Oct-Dec;4:33-8.
6. Sandalcioglu LE, Schoch B, Regel JP, Wanke I, Gasser T, Forsting M, *et al.* Does intraoperative aneurysm rupture influence outcome? Analysis of 169 patients. Clin Neurol Neurosurg. 2004;106:88-92.
7. Giannotta SL, Oppenheimer JH, Levy ML, Zelman V. Management of intraoperative rupture of aneurysm without hypotension. Neurosurgery. 1991;28:531-6.
8. Kassell NF, Boarini DJ, Adams HP, Sahs AL, Graf CJ, Tarner JC, *et al.* Overall management of ruptured aneurysm: comparison of early and later operation. Neurosurgery. 1981;9:120-8.
9. Le Roux PD, Elliott JP, Newell DW, Grady MS, Winn HR. The incidence of surgical complications is similar in good and poor grade patients undergoing repair of ruptured anterior circulation aneurysms: a retrospective review of 355 patients. Neurosurgery. 1996;38:887-95.
10. Schramm J, Cedzich C. Outcome and management of intraoperative aneurysm rupture. Surg Neurol. 1993;40:26-30.
11. Levy E, Koebbe CJ, Horowitz MB, Jungreis CA, Pride GL, Dutton K, *et al.* Rupture of intracranial aneurysm during endovascular coiling: management and outcomes. Neurosurgery. 2001;49:807-11.
12. Sluzewski M, Bosch JA, van Rooij WJ, Nijssen PC, Wijnalda D. Rupture of intracranial aneurysms during treatment with Guglielmi detachable coils. Incidence, outcome and risk factors. J Neurosurg. 2001;90:238-40.
13. Batjer H, Samson D. Intraoperative aneurysmal rupture: incidence, outcome and suggestions for surgical management. Neurosurgery. 1986;18:701-7.
14. Peerles S, Hernesniemi J, Gutman F, Drake C. Early surgery for ruptured vertebrobasilar aneurysms. J Neurosurg. 1994;80:643-9.
15. Brisman J, Niimi Y, Song J, Berenstein A. Aneurysmal rupture during coiling: low incidence and good outcomes at a single large volume center. Neurosurgery. 2008;62(Suppl 3):1525-31.
16. Gupta M, Bithal P, Dash H, Chaturvedi A, Prabhakar H. Clinical outcome of intracranial aneurysms: a retrospective comparison between endovascular coiling and neurosurgical clipping. Indian J Anesth. 2008;25:63-9.
17. Choi SS, Jean SJ. Comprehension of two modalities: endovascular coiling and microsurgical clipping in treatment of intracranial aneurysms. Neurointervention. 2010;5:1-7.
18. Heros R. International subarachnoid aneurysm trial analysis. J Neurosurg. 2008;108:433-6.
19. Molyneux A, Kerr R, Yu L, Clarke M, Sneade M, Yarnold J, *et al.* International Subarachnoid Aneurysm Trial (ISAT) of neurosurgical clipping *versus* endovascular coiling in 2143 patients with ruptured intracranial aneurysms: a randomized comparison of effects on survival, dependency, seizures, rebleeding, subgroups and aneurysm occlusion. Lancet. 2005;366:809-17.
20. Koivisto T, Vanninen R, Hurskainen H, Saari T, Hernesniemi J, Vapalahti M. Outcomes of early endovascular *versus* surgical treatment of ruptured cerebral aneurysms. A prospective randomized study. Stroke. 2000;31:2369-77.
21. Raftapoulos C, Vaz G. Surgical indications and techniques for failed coiled aneurysms. In: Pickard JD, editor. Advances and Technical Standards in Neurosurgery. Wien-New York: Springer; 2011; p. 199-226.
22. Spetzler R, McDougall C, Albuquerque F, Zabramski J, Hills N, Partovi Sh, *et al.* The Barrow ruptured aneurysm trial: 3-year results. J Neurosurg. 2013;119:146-57.
23. Chandler JP, Getch CC, Batjer HH. Intraoperative aneurysm rupture and complication avoidance. Neurosurg Clin North Am. 1998;9:861-8.
24. Lawton M, Du R. Effect of the neurosurgeon's experience on outcomes from intraoperative aneurysmal rupture. Neurosurgery. 2005;57:9-15.
25. Fridriksson S, Saveland M, Jakobsson K, Edner G, Zygmunt S, Brandt L, *et al.* Intraoperative complications in aneurysm surgery. J Neurosurg. 2002;96:515-22.
26. Cloft H, Kallmes D. Cerebral aneurysm perforations complicating therapy with Guglielmi detachable coils: a meta-analysis. AJNR Am J Neuroradiol. 2002;23:1706-9.
27. Valavanis A, Machado E, Chen J. Aneurysm rupture during GDC treatment: incidence, management and outcome. Neuroradiology. 1996;38(Suppl 2):45.
28. Doerfler A, Wanke I, Egelhof T, Dietrich U, Asgari S, Stolke D, *et al.* Aneurysmal rupture during embolization with Guglielmi detachable coils: causes, management and outcome. AJNR Am J Neuroradiol. 2001;22:1825-32.
29. Ricolfi F, Guerinel C, Blustain J, Combes C, Brungieres P, Melan E, *et al.* Rupture during treatment of recently ruptured aneurysms with Guglielmi electrodetachable coils. AJNR Am J Neuroradiol. 1998;19:1653-8.
30. McDougall CG, Halbach VV, Dowd CF, Higashida RT, Larsen DW, Hieshima GB. Causes and management of aneurysmal hemorrhage occurring during embolization with Guglielmi detachable coils. J Neurosurg. 1998;89:87-92.
31. Saito H, Hayakawa K, Nishimura M, Okano Y, Muramaya C, Miyazawa T, *et al.* Intracarotid blood pressure changes during contrast medium injection. AJNR Am J Neuroradiol. 1996;17:51-4.

Sažetak

INTRAOPERACIJSKA RUPTURA ANEURIZME: KLINIČKI ISHOD NAKON OTVORENOG KIRURŠKOG ZAHVATA ILI ENDOVASKULARNOG POSTUPKA

N. Lakićević, B. Prstojević, L. Rasulić, Lj. Vujotić, I. Vukašinović, B. Miličić, A. Savić, B. Živković, K. Rotim i *M. Samardžić*

Cilj ovoga istraživanja bio je procijeniti i usporediti ishod liječenja nakon intraoperacijske rupture aneurizme u bolesnika sa subarahnoidnom hemoragijom kod kojih je proveden kirurški ili endovaskularni zahvat. U ovu retrospektivnu studiju bilo je uključeno 742 bolesnika liječenih zbog spontane subarahnoidne hemoragije u Klinici za neurokirurgiju Kliničkog centra Srbije u razdoblju d tri godine. Među njima je 167 (31,15%) liječeno kirurškim, a 33 (16,01%) endovaskularnim zahvatom u ranoj fazi (≤72 sata). Opći ishod liječenja i prijeoperacijske varijable su analizirane za obje skupine bolesnika, uključujući njihovu uspredbu u odnosu na pojavu intraoperacijske rupture aneurizme u ovim skupinama. Intraoperacijska ruptura aneurizme se javila u 14,7% kirurški liječenih i 2,4% endovaskularno liječenih bolesnika. Češće je zabilježena kod bolesnika liječenih u ranoj fazi u usporedbi s onima liječenim u odloženom terminu (27,5% i 9,7%, odnosno 2,2% i 1,1%). Nasuprot tome, smrtnost je bila niža u skupini kirurški liječenih bolesnika (11,4%) nego u skupini bolesnika liječenih endovaskularnim postupkom (60,0%). Na osnovi rezultata dobivenih u ovoj studiji zaključuje se da je intraoperacijska ruptura aneurizme češća tijekom otvorenog kirurškog zahvata u odnosu na endovaskularni, ali da je klinički ishod povoljniji u prvoj skupini.

Ključne riječi: *Intrakranijska aneurizma – kirurgija; Intraoperacijske komplikacije; Aneurizma, ruptura; Subarahnoidno krvarenje; Klipse za aneurizme*